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(54) Piezoelectric Bimorphs and Driver Circuits

(57) A cantilevered bimorph 10 has a pair of oppositely polarised piezo-ceramic elements 18 bonded to a common substrate 16; and a drive circuit applies a deflection voltage to each element in the same sense as the polarisation of the element. Depolarisation of the piezo-ceramic elements is thus avoided. The circuit applies a common bias voltage and also oppositely phased A.C. deflection signals to the elements.

Fig.1.

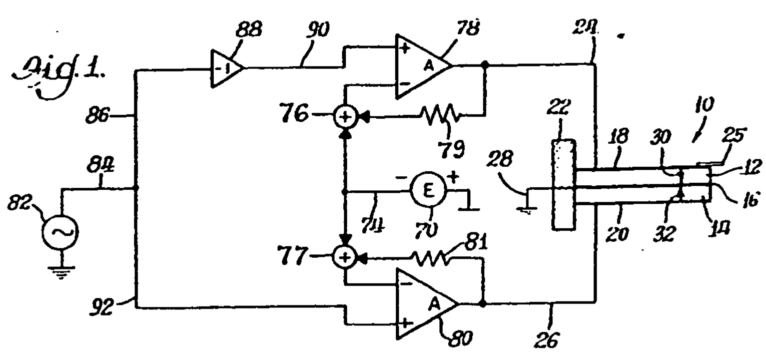

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Fig.1.

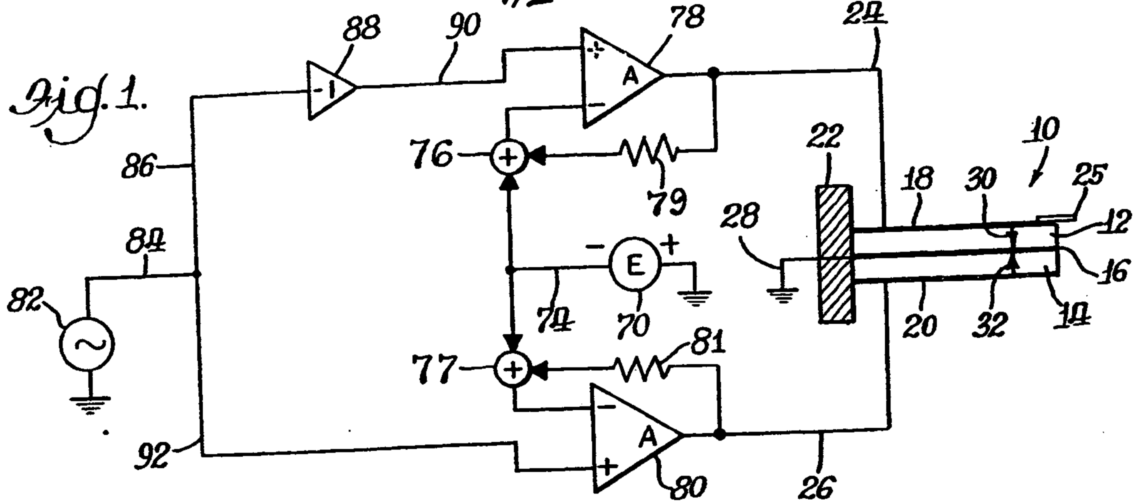


Fig.2

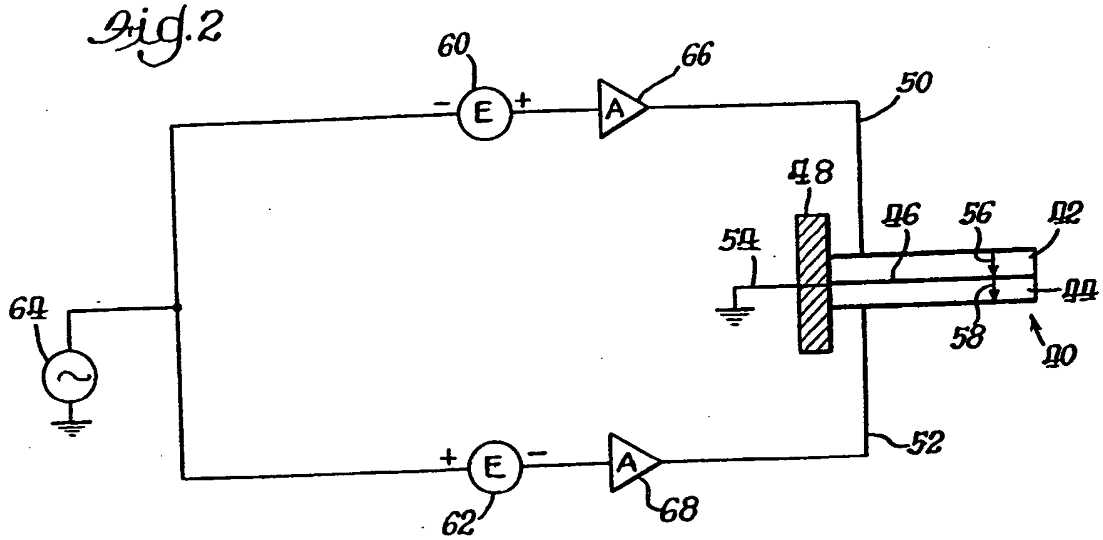


Fig.3.

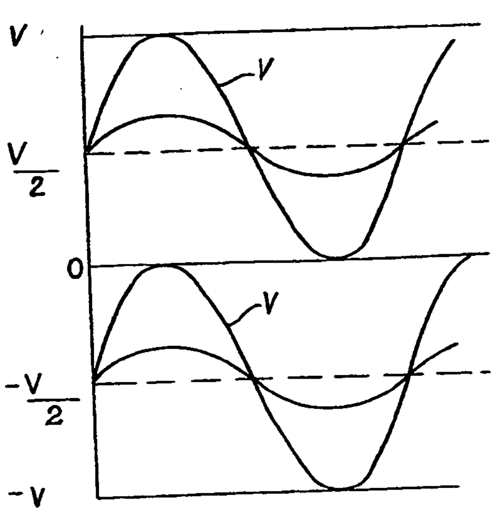
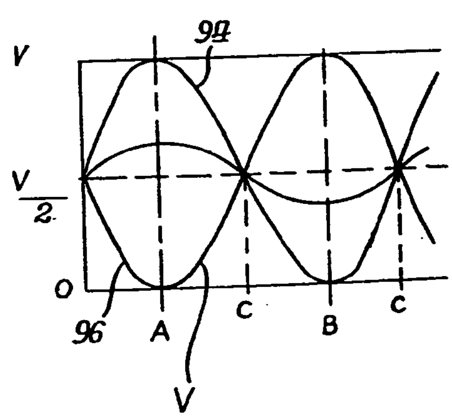
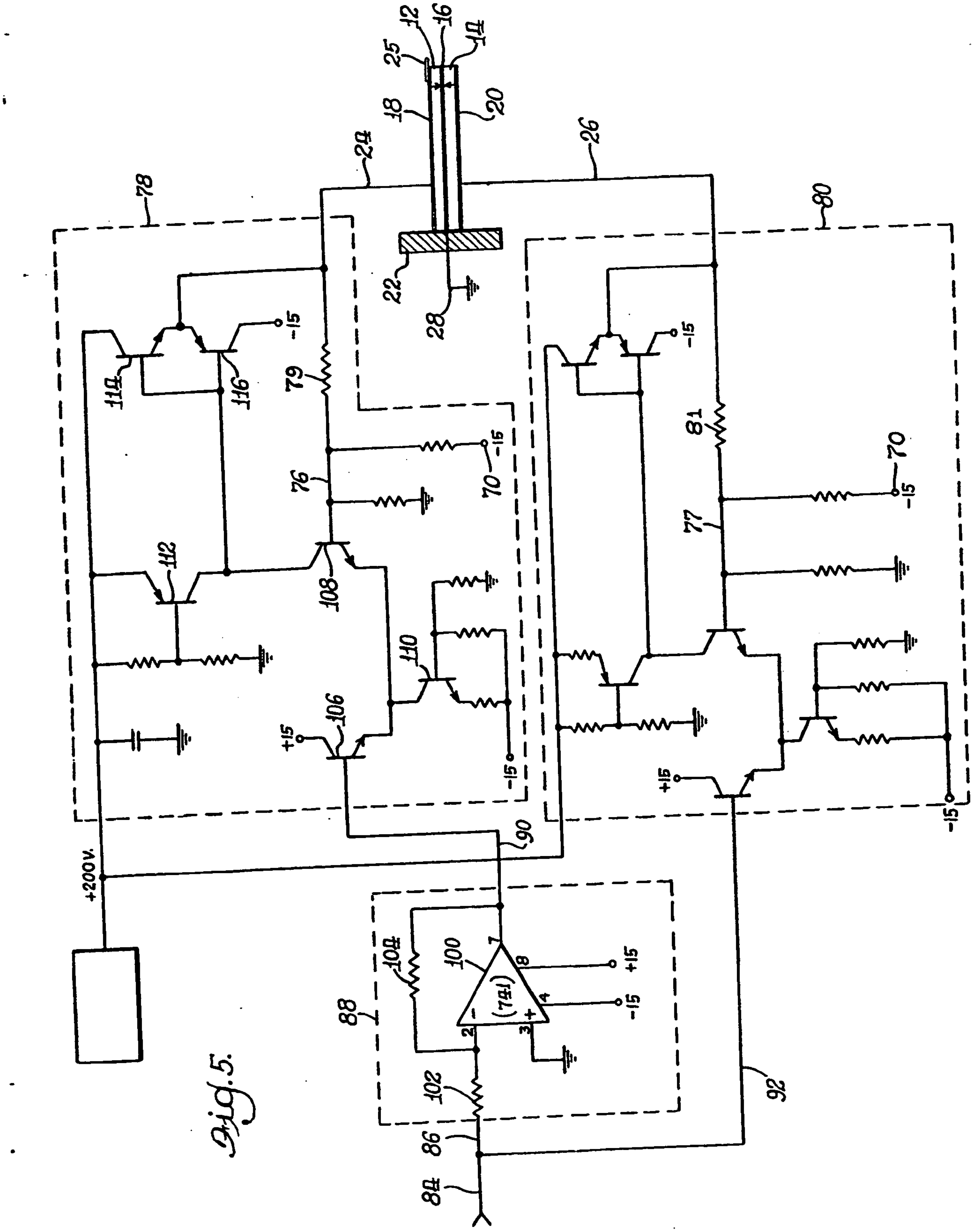


Fig.4.





12
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-15
+15
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106
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+200V.
88
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104
(741)
102
86
84

Fig.5.

SPECIFICATION

Piezoelectric Bimorphs and Driver Circuits for Them

The present invention relates to piezoelectric benders, particularly cantilevered bimorphs and driver circuits for them.

The invention is particularly, though by no means exclusively, intended for use in a rotary scan tape recorder, particularly a helical scan recorder, in which a magnetic transducer is mounted on a bimorph which is fixed to a rotary scanning assembly and the bimorph is deflected under the control of electrical signals so that the transducer may be accurately positioned relative to a recorded track, or kept on a desired course during recording. The invention is also useful in analogous circumstances in recording and playback apparatus employing floppy discs and, as will be seen, in other apparatus in which the deflection due to bending of the bimorph is required to be large.

It is well-known to bond together a pair of piezoelectric elements, which may be composed of a suitable ceramic, and to apply a voltage to the elements to cause them to flex. The pair of elements is usually called a bimorph. The elements themselves usually consist of a polycrystalline material of high dielectric constant. Such a material acquires piezoelectric properties when it is subjected to a strong unidirectional electric field which polarises the material according to the polarity of the voltage which is applied to produce the field. The polarised material is then piezoelectrically anisotropic, the direction of the polarisation sometimes being termed "a poling direction". The polarised material has particular dynamic properties when it is subjected to subsequently applied voltages. It has been proposed to multiply the bending effect of a single piezoelectric element by the bonding of a piezoelectric element to each side of a substrate and the application of respective voltages between the substrate and the outer surfaces of each element, so that for one element the voltage and the prior polarisation are in the same sense and for the other element the applied voltage and a prior polarisation are opposed. The elements of the bimorph work in "push-pull" and provide quite large deflections. However, it has been found that when large amounts of bending are required, the necessarily large deflection voltages tend to depolarise the element when the voltages are of a polarity opposite that of the piezoelectric polarisation of an element, the applied voltage being then opposite to that of the original polarising voltage for the element. The depolarisation of an element reduces its ability to bend.

It has been proposed, as will be explained in more detail later, in our prior co-pending Application No. 10991/77 to dispose the elements in the bimorph such that their piezoelectric polarisations are in the same direction and to apply deflection voltages in a manner which avoids depolarisation of the elements.

The present invention provides a piezoelectric bimorph and a driver circuit, in which the said bimorph comprises a pair of superposed piezoelectric elements of which the directions of polarisation are mutually opposite and in which the driver circuit is arranged to apply to the elements deflection voltages, each of which is of the same polarity as the polarisation of the respective element, in such manner that neither element is depolarised by the respective applied voltage.

Reference will now be made to the accompanying drawings, in which:—

Figure 1 is a schematic diagram of a system comprising a driver circuit and a bimorph disposed in accordance with the present invention;

Figure 2 illustrates for comparison with Figure 1, an arrangement as disclosed in the aforementioned Application No. 10991/77;

Figure 3 is a graph illustrating the waveforms of deflection voltages applied according to the proposals of the aforementioned co-pending application;

Figure 4 illustrates the waveforms of deflection voltages applied by a system as described with reference to Figure 1; and

Figure 5 is a diagram of a particular circuit embodying the systems shown schematically in Figure 1.

The bimorph and driver circuit which are illustrated in Figure 1 are particularly suitable for incorporation in a video tape recorder which incorporates automatic control of a transducer relative to a desired track as described in our co-pending Patent Application Nos. 9100/77 and 10036/77, but the system described in Figure 1 is intended to have a more general utility. As will be apparent from what follows, the system is intended to provide deflections of large amplitude in a deflectable bimorph without the production of depolarisation of the bimorph's elements. In the preferred embodiment that will be described, a unidirectional bias voltage is applied to each element, this voltage being of the same polarity as a polarisation of the element, and an alternating voltage is superimposed on the bias voltage in order to produce flexing of the bimorph. The deflection voltages applied to the elements are of opposite phase and the magnitude of the bias voltage is such to ensure that the nett voltage on an element has always the same polarity as the "poling direction" of that element.

Figure 1 illustrates one embodiment of the present invention, in which an elongate deflectable bimorph 10 which acts as a piezoelectric motor, comprises an upper piezo-ceramic laminar element 12, a lower piezo-ceramic lamina element 14 and an intermediate electrically conductive substrate 16 which is bonded to the upper and lower elements 12 and 14. The substrate 16 limits the movement of the

bimorph to bending in response to an applied electric potential difference.

To enable an electrical potential difference to be applied to the elements 12 and 14, conductive layers 18 and 20 are provided to cover the exposed surfaces of the elements. The bimorph 10 is supported at its lefthand end by a support 22 and is cantilevered therefrom. The bimorph's free end carries a transducer 25, the electrical connections of which are not shown but which extend to the circuit associated with playing back signals from, and recording signals on, a magnetic video tape.

To impress an electrical potential difference to the elements 12 and 14 and thereby to deflect the bimorph, a voltage is applied to lines 24 and 26 which are connected to the layer 18 and to the layer 20 respectively. The substrate 16 between the elements 12 and 14 has a connection 28 to earth.

The direction in which the bimorph deflects depends on the polarity of the voltage applied to it and upon the polarisation of the pair of piezo-ceramic elements. The sense of polarisation of a piezo-ceramic element is initially established by subjecting the element to a unidirectional electric field which polarises the element according to the direction of the field. The arrows 30 and 32 indicate the senses in which the elements 12 and 14 are respectively polarised.

Before the remainder of the system shown in Figure 1 is described, reference will be made for comparison to Figure 2 which illustrates schematically a bimorph 40, which comprises a pair of piezo-ceramic elements 42 and 44 that are bonded to a substrate 46 and which is also anchored to a support 48 and is deflected by the application of biasing voltages *via* lines 50, 52 and 54. The deflection of the bimorph 40 will be described in accordance with the method and structure described in our co-pending Patent Application No. 10991/77. The piezo-ceramic elements shown in Figure 2 differ from those of Figure 1 in that both elements 42 and 44 have a common direction of polarisation; the arrows 56 and 58 are in the same direction.

In the circuit shown in Figure 2, bias voltage sources 60 and 62 each provide a D.C. voltage for combination with an alternating voltage supplied by a source 64. The bias voltage source 60 is coupled between the source 64 and the input of an amplifier 66, the output of the amplifier 66 being coupled to the element 42 by a line 50. The bias voltage source 62 is coupled between the source 64 and the input of an amplifier 68, the output of the amplifier being coupled to the element 44 by a line 52.

Deflection voltages are applied to the elements 42 and 44 such that the polarity of the applied voltage is always in the direction of initial polarisation of the element to which it is applied so that a large deflection of the bimorph can be effected without depolarisation of either piezo-ceramic element. Accordingly, the elements being polarised as indicated by the arrows 56 and 58, the voltage sources 60 have opposite polarities with respect to the source 64.

The sources 60 and 62 generate D.C. voltages having magnitudes equal to 1/2 V_{max} where V_{max} is the peak-to-peak amplitude of the largest deflection signal that will be applied to the respective elements 42 and 44. The elements 42 and 44 are thus oppositely "biased" to 1/2 V_{max} and, in the absence of any other deflection voltage, the bimorph 40 would experience no deflection. For effecting varying amounts of deflection of the bimorph, the voltage from the source 64 is coupled between the elements 42 and 44 through the D.C. sources 60 and 62 and the amplifiers 66 and 68. The peak-to-peak amplitude of the A.C. deflection voltage applied to the elements 42 and 44 may not be greater than V_{max} lest there be applied to either element a nett voltage of a polarity which is opposed to the direction of polarisation. When the deflection voltage from the source 64 varies sinusoidally, the nett voltage which appears across the element 42 is indicated in the upper half of the graph shown in Figure 3 and the nett voltage on the element 44 is illustrated in the lower half of the graph. The elements 42 and 44 being oppositely biased at 1/2 V_{max} and the superimposed A.C. deflection signal being applied to each of the elements, the nett voltage across each of the elements 42 and 44 always has a polarity which is in the direction of polarisation. The curves labelled "deflection" in Figure 3 indicate that the bimorph 40 deflects according to twice the instantaneous magnitude of the A.C. deflection voltage applied by the source 64. When the nett voltage on element 42 becomes more (or less) positive than 1/2 V_{max}, the nett voltage on element 44 becomes less (or more) negative correspondingly. However, because of the bias provided by the voltage source 62, the nett voltage on the element 44 will always be in the direction of polarisation provided that the peak-to-peak magnitude of the A.C. deflection voltage does not exceed V_{max}.

It should be appreciated from the schematic diagram of Figure 2 that a positive as well as negative power supply is required to provide the proper bias for the two elements 42 and 44 of the bimorph.

In the system shown in Figure 1, only one power supply is needed because the directions of polarisation of the bimorph's elements 12 and 14 are opposed. The particular circuit has a single D.C. biasing source 70 of which the negative terminal is connected *via* a line 74 to summing junctions 76 and 77 which are connected to respective inverting inputs of amplifiers 78 and 80 whose outputs are connected to lines 24 and 26 respectively. The positive terminal of the D.C. biasing source 70 is earthed. An alternating voltage source 82 is connected *via* lines 84 and 86 to an inverting amplifier 88 (of negative unity gain) which changes the phase of the signal produced by the source 82 applied to the non-inverting input of the amplifier 78 *via* a line 90.

The source 82 is directly connected to the non-inverting input of the amplifier 80 *via* lines 84 and 92. A feedback resistor 79 is coupled between the output of the amplifier 78 and the summing junction 76. Similarly, a feedback resistor 81 is coupled between the output of the amplifier 80 and the summing junction 77.

If, as may be presumed for the sake of analysis, the source 82 generates a sinusoidal signal the voltage that appears at the output of the amplifier 80 has the waveform 94 shown in Figure 4. The signal is inverted by the amplifier 88 so that an inverted signal appears on line 24 at the output of the amplifier 78; this inverted signal is represented by the waveform 96 in Figure 4.

Since the summing junctions are coupled to the inverting inputs of the amplifiers 78 and 80, a composite or nett voltage is applied to the respective elements 12 and 14 in a manner whereby as is illustrated by Figure 4 a negative voltage never appears on either element. The D.C. bias voltage level is preferably set at half the maximum voltage and the A.C. deflection source 82 preferably has a maximum voltage which equals the D.C. bias voltage so that when it is in the positive direction, the voltage applied to a piezo-ceramic element may reach the maximum voltage. Also, when the deflection source voltage is negative relative to the D.C. bias voltage, the composite voltage can be reduced approximately to zero. It may be noted that all the indicated polarities can be reversed to accomplish the same result.

Owing to the amplifier 88, the waveform appearing at the summing junction 76 is always opposite that appearing at the summing junction 77 and the bending of the bimorph can thereby be achieved. If the instantaneous deflection voltages are as shown at A in Figure 4, the voltage (94) applied to the element 14 is at its maximum whereas the voltage (96) applied to the element 12 is approximately zero. Since the polarity of the voltage applied to the lower element is the same as that of the polarisation of the element, the bimorph will bend upwardly as viewed in Figure 1. Similarly, if the voltages are as shown at B in Figure 4, i.e. maximum voltage being applied to the piezo-ceramic element 12 and approximately zero voltage being applied to the lower element 14 as shown by curve 94, a voltage will be applied in the same polarity as that of the polarisation of the piezo-ceramic element 12 and the bimorph will deflect downwardly. For no deflection the A.C. deflection voltages are zero as shown at C and equal D.C. biasing voltages are applied to the piezo-ceramic elements.

In practice the source 82 may provide a waveform more complex than a pure sinusoid but the greater complexity is not important as far as the present invention is concerned. The source may in practice provide a complex deflection signal that maintains the transducer 25 on a desired path, such as a recorded track during playback or a predetermined path during recording.

An embodiment of the invention, corresponding to the system, shown schematically by Figure 1, is shown in Figure 5; it receives on a line 84 an A.C. deflection signal from a suitable source of which the particular form is not part of the present invention. The amplifier 88 of Figure 1 is constituted by an operational amplifier 100 of which the input resistor 102 and the feedback resistor 104 are proportioned to provide a negative unity gain; the amplifier provides at an output 90 a signal in anti-phase to the signal on the input 84. The input signal is conveyed by a line 92 to the amplifier 80. The amplifiers 78 and 80 are substantially similar. The amplifier 78 comprises a differential pair of transistors 106 and 108, a transistor 110 providing a current source bias for the differential pair. A transistor 112 provides a current bias for the transistor 108. Two transistors 114 and 116 are arranged as push-pull class B emitter followers which amplify the current for driving the bimorph, which is a capacitive load. A feedback resistor 79 is used to stabilise the gain of the amplifier 78. The amplifiers 78 and 80 may have, for example, a gain of about ten if the bimorph requires maximum deflecting voltags of about 200 volts.

Claims

1. A piezoelectric bimorph and a driver circuit, in which the said bimorph comprises a pair of superposed piezoelectric elements of which the directions of the polarisation are mutually opposite, and the driver circuit is arranged to apply to the elements deflection voltages, each of which is of the same polarity as the polarisation of the respective element, in such manner that neither element is depolarised by the respective applied voltage.

2. A piezoelectric bimorph and driver circuit according to claim 1, in which an electrically conductive lamina is disposed between the said elements and is bonded to them.

3. A piezoelectric bimorph according to claim 2, in which the deflection voltage for each element is applied between the conductive lamina and a face of the respective element, this face being opposite to that to which the conductive lamina is bonded.

4. A piezoelectric bimorph and driver circuit according to any foregoing claim, in which the deflection voltages each comprise two components, of which one is a unidirectional bias voltage which is of the same polarity for each element and of which the other component is an alternating voltage which is superimposed on the respective bias voltage, the alternating voltages for the two elements being of opposite phase.

5. A piezoelectric bimorph and a driver circuit according to claim 4, in which the alternating voltages are obtained from a common source, one of the said alternating voltages being obtained by means of a phase inverter fed by the said source.

6. A piezoelectric bimorph and a driver circuit according to claim 4 or claim 5, in which the alternating voltages are separately combined with

similar bias voltages obtained from a common source of direct voltage.

7. A piezoelectric bimorph and a driver circuit according to any foregoing claim, in which the said bimorph constitutes a cantilever so that the bending of the bimorph produces lateral deflection of the free end of the cantilever.

8. An assembly comprising a piezoelectric bimorph and driver circuit according to claim 7, in which the said bimorph carries a transducer at the said free end.

9. A method of driving a cantilevered piezoelectric bimorph constituted by a pair of electrically polarised ceramic elements of which the polarisations are in mutually opposite directions and which are bonded to a common conductive substrate disposed between the elements, the method comprising applying deflection voltages to each element such that the polarity of the voltage applied to each element corresponds to the sense in which the respective element is polarised, so that the deflection voltages do not depolarise either element.

10. A piezoelectric bimorph and driver circuit, substantially as hereinbefore described with reference to Figure 1 of the accompanying drawings.

11. A piezoelectric bimorph and driver circuit, substantially as hereinbefore described with reference to Figure 5 of the accompanying drawings.

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